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(54) **Drillable well bore packing apparatus.**

(57) A downhole well bore packing apparatus (eg. a packer or bridge plug) includes a component which bears compressive loading and is made of plastics material. Such components can be lock ring housings (24), slips (28,54), slip wedges (32,46) or slip supports (24,58) for example. After use of the packing apparatus downhole, it can be relatively easily drilled out.

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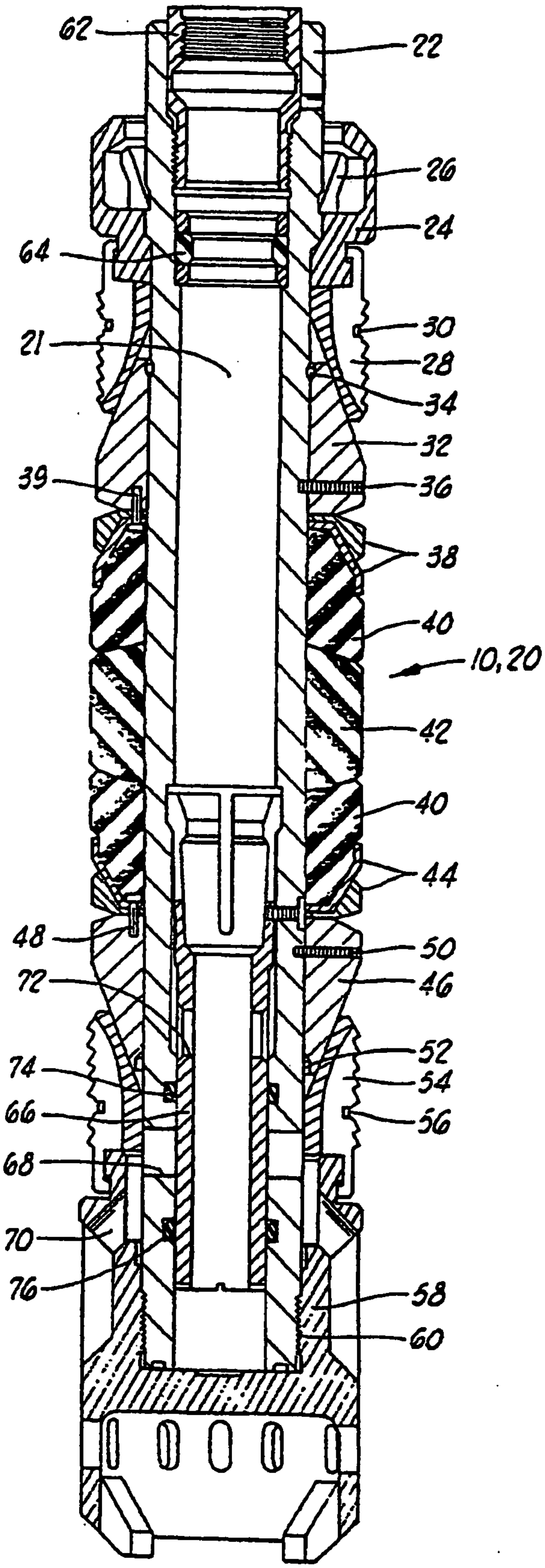

FIG. 2

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This invention relates to packing apparatus for use in a well bore and to its subsequent removal from the well bore.

In the drilling or reworking of oil wells, it is often desirable to seal tubing or other pipe in the casing of the well. For example, when it is desired to pump cement or other slurry down tubing and force the slurry out into a formation, it becomes necessary to seal the tubing to the well casing and to prevent the fluid pressure of the slurry from lifting the tubing out of the well. Packers and bridge plugs designed for these general purposes are well known in the art.

When it is desired to remove many of these packers and plugs from a well bore, it is frequently simpler and less expensive to mill or drill the packer out rather than to implement a complex retrieving operation. In milling, a milling cutter is used to grind the packer or plug, or at least the outer components thereof, out of the well bore. Milling is a relatively slow process, but it can be used on packers or bridge plugs having relatively hard components such as erosion-resistant hard steel. One such packer is described in our U.S. patent specification no. 4,151,875 (Sullaway) and sold under the trademark EZ Disposal™ packer.

In drilling, a drill bit is used to cut and grind up the components of the packer or bridge plug to remove it from the well bore. This is a much faster operation than milling, but it requires the packer or bridge plug to be made out of materials which can be accommodated by the drill bit. Typically, soft and medium hardness cast iron are used on the pressure bearing components, along with some brass and aluminium items. Packers of this type include the Halliburton EZ Drill[R] and EZ Drill SV[R] squeeze packers.

The EZ Drill SV[R] squeeze packer, for example, includes a lock ring housing, upper slip wedge, lower slip wedge, and lower slip support made of soft cast iron. These components are mounted on a mandrel made of medium hardness cast iron. The EZ Drill[R] squeeze packer is similarly constructed. The Halliburton EZ Drill[R] bridge plug is also similar, except that it does not provide for fluid flow therethrough.

All of the above-mentioned packers are described in Halliburton Services Sales and Service Catalog No. 43, pages 2561-2562, and the bridge plug is disclosed in the same catalog on pages 2556-2557.

The EZ Drill[R] packer and bridge plug and the EZ Drill SV[R] packer are designed for fast removal from the well bore by either rotary of cable tool drilling methods. Many of the components in these drillable packing devices are locked together to prevent their spinning while being drilled, and the harder slips are grooved so that they will be broken up into small pieces. Typically, standard "tri-cone" rotary drill bits are used which are rotated at speeds of about 75 to about 120 rpm. A load of about 5,000 to about 7,000 pounds (2270 to 3180 kg) of weight is applied to the bit for initial drilling and increased as necessary to drill out the remainder of the packer or bridge plug, depending upon its size. Drill collars may be used as required for weight and bit stabilization.

These drillable packing devices have worked well and provide improved operating performance at relatively high temperatures and pressure. The packers and plug are designed to withstand pressures of about 10,000 psi (68.9 MPa) and temperatures of about 425°F (218°C) after being set in the well bore. Such pressures and temperatures require the cast iron components previously discussed.

However, drilling out iron components requires certain techniques. Ideally, the operator employs variations in rotary speed and bit weight to help break up the metal parts and re-establish bit penetration should bit penetration cease while drilling. A phenomenon known as "bit tracking" can occur, wherein the drill bit stays on one path and no longer cuts into the packer plug. When this happens, it is necessary to pick up the bit above the drilling surface and rapidly recontact the bit with the packer or plug and apply weight while continuing rotation. This aids in breaking up the established bit pattern and helps to re-establish bit penetration. If this procedure is used, there are rarely problems. However, operators may not apply these techniques or even recognize when bit tracking has occurred. The results is that drilling times are greatly increased because the bit merely wears against the surface of the packer or plug rather than cutting into it to break it up.

While cast iron components may be necessary for the high pressures and temperatures for which they are designed, it has been determined that most wells cemented throughout the world experience pressures less than 10,000 psi (68.9 MPa) and temperatures less than 425°F (218°C). In fact, in the majority of wells, the pressure is less than about 5,000 psi (34.5 MPa), and the temperature is less than about 250°F (121°C). Thus, the heavy duty metal construction of the previous packers and bridge plugs described above is not necessary for many applications, and if cast iron components can be eliminated or minimized, the potential drilling problems resulting from bit tracking might be avoided as well.

We have now sucessfully tackled this problem by providing packers and bridge plugs wherein at least some of the components, including pressure bearing components, are made of plastics material rather than of metal. Such plastics components are much more easily drilled than cast iron, and new drilling methods may be employed which use alternative drill bits such as polycrystalline diamond compact bits, or the like, rather than standard tri-cone bits.

According to the present invention, there is provided a well bore process which comprises the steps of positioning a well packing device into sealing engagement with the well bore; and subsequently drilling said device out of said well bore, characterised in

that the device includes a component subject to substantially compressive loading which is made of a plastics material.

The invention also includes a well bore packing apparatus which comprises a centre mandrel; slip means disposed on said mandrel for grippingly engaging said well bore, said slip means comprising a slip wedge made of plastics material; and packing means disposed on said mandrel for sealingly engaging said well bore when in a set position.

The well bore packing apparatus of the present invention utilizes the same general geometric configuration of previously know drillable packers and bridge plugs, but replaces at least some of the metal components with engineering grade plastics which can still withstand the pressures and temperatures exposed thereto in many well bore applications. The plastic components are easier to drill out and allow the use of alternative drilling techniques to those previously known.

A preferred component in the slip means to be made of plastics may be, for example, a lock ring housing, a slip, a slip wedge or a slip support. The slips themselves may require the addition of hardened inserts for the actual engagement with the well bore. The slip means may be an upper slip means disposed above the packing means, and the apparatus may further comprise a lower slip means disposed below the packing means, the lower slip means also comprising a component made of a plastic material.

Most of the components of the slip means are subjected to substantially compressive loading when in a sealed operating position in the well bore, although some tensile loading may also be experienced. The centre mandrel typically has tensile loading applied thereto when setting the packer and when the packer is in its operating position. In another embodiment, the mandrel may also be made of a plastics material.

One preferred plastics material for at least some of these components is a glass reinforced phenolic resin, preferably one having a tensile strength of about 18,000 psi (124 MPa) and a compressive strength of about 40,000 psi (276 MPa), although the invention is not intended to be limited to this particular plastic or to a plastic having these specific physical properties. The plastics materials are preferably selected such that the packing apparatus can withstand well pressures less than about 10,000 psi (68.9 MPa) and temperatures less than about 425°F (218°C). In one preferred embodiment, but not by way of limitation, the plastics materials of the packing apparatus are selected such that the apparatus can withstand well pressures up to about 5,000 psi (34.5 MPa) and temperatures up to about 250°F (121°C).

In the method of the invention, the well packing device is preferably a packer or bridge plug, and the plastic component therein is preferably selected from at least one of the lock rings housings, slip wedges and slip supports as previously mentioned. The device may also include a component subject to at least some tensile loading, which is also made of plastics material. This plastics component subject to tensile loading may for example be the centre mandrel of the packing device.

Preferably, the step of drilling is carried out using a polycrystalline diamond compact bit. Regardless of the type of drill bit used, the process may further comprise the step of drilling using a drill bit without substantially varying the weight applied to the drill bit.

In another aspect of the invention, the well bore process can comprise the steps of positioning and setting a packer or plug in the well bore, a portion of the packer or plug being made of engineering grade plastic; contacting the packer or plug with well fluids; and then drilling out the packer or plug using a drill bit having no moving parts, such as a polycrystalline diamond compact bit. This or a similar drill bit might have been previously used in drilling the well bore itself, so the process may be said to further comprise the step of, prior to the step of positioning and setting the packer, drilling at least a portion of the well bore using a drill bit such as a polycrystalline diamond compact bit.

In one preferred embodiment, the step of contacting the packer is at a pressure of less than about 5,000 psi (34.5 MPa) and a temperature of less than about 250°F (121°C), although higher pressures and temperatures may also be encountered.

In order that the invention may be more fully understood, reference is made to the accompanying drawings, wherein:

FIG. 1 illustrates an embodiment of packing apparatus of the present invention positioned in a well bore with a drill bit disposed thereabove; and

FIG. 2 illustrates in axial section one embodiment of drillable packer made in accordance with the invention.

Referring now to the drawings, and more particularly to FIG. 1, the well bore packing apparatus of the present invention is shown and generally designated by the numeral 10. Apparatus 10 is shown in a sealing, operating position in a well bore 12. Apparatus 10 can be set in this position by any manner known in the art such as setting on a tubing string or wire line. A drill bit 14 connected to the end of a tool or tubing string 16 is shown above apparatus 10 in a position to commence the drilling out of apparatus 10 from well bore 12. Methods of drilling out apparatus 10 will be further discussed herein.

Referring now to FIG. 2, the details of a squeeze packer embodiment 20 of packing apparatus 10 will be described. The size and configuration of packer 20 is substantially the same as the previously described prior art EZ Drill SV® squeeze packer. Packer 20 defines a generally central opening 21 therein.

Packer 20 comprises a center mandrel 22 on which most of the other components are mounted. A lock ring housing 24 is disposed around an upper end of mandrel 22 and generally encloses a lock ring 26.

Disposed below lock ring housing 24 and pivotally-connected thereto are a plurality of upper slips 28 initially held in place by a retaining band 30. A generally conical upper slip wedge is disposed around mandrel 22 adjacent to upper slips 30. Upper slip wedge 32 is held in place on mandrel 22 by a wedge retaining ring 34 and a plurality of screws 36.

Adjacent to the lower end of upper slip wedge 32 is an upper expanding shoe 38 connected to the upper slip wedge by a pin 39. Below upper expanding shoe 38 are a pair of end packer elements 40 separated by center packer element 42. A lower expanding shoe 44 is disposed adjacent to the lowermost end packer element 40.

A generally conical lower slip wedge 46 is positioned around mandrel 22 adjacent to lower expanding shoe 44, and a pin 48 connects the lower expanding shoe to the lower slip wedge.

Lower slip wedge 46 is initially attached to mandrel 22 by a plurality of screws 50 and a wedge retaining ring 52 in a manner similar to that for upper slip wedge 32. A plurality of lower slips 54 are disposed adjacent to lower slip wedge 46 are are initially held in place by a retaining band 56. Lower slips 54 are pivotally connected to the upper end of a lower slip support 58. Mandrel 22 is attached to lower slip support 58 at threaded connection 60.

Disposed in mandrel 22 at the upper end thereof is a tension sleeve 62 below which is an internal seal 64. A sliding valve 66 is slidably disposed in central opening 21 at the lower end of mandrel 22 adjacent to fluid ports 68 in the mandrel. Fluid ports 68 in mandrel 22 are in communication with fluid ports 70 in lower slip housing 58. The lower end of lower slip support 58 is closed below ports 70.

Sliding valve 66 defines a plurality of valve ports 72 which can be aligned with fluid ports 68 in mandrel 22 when sliding valve 66 is in an open position. Thus, fluid can flow through central opening 21. As illustrated in FIG. 2, sliding valve 66 is in a closed position wherein fluid ports 68 are sealed by upper and lower valve seals 74 and 76. Opening and closing of valve 66 is in a manner known in the art.

Packer 20 is positioned in well bore 12 and set into gripping and sealing engagement therewith in a manner substantially identical to similar packers and plugs of the prior art. Full details of this setting operation are disclosed in the above-referenced U. S. Patent No. 4,151,875 to Sullaway, a copy of which is included herein by reference, so only a brief description of the setting operation will be described herein.

By pulling upwardly on mandrel 22 while holding lock ring housing 24, the lock ring housing is moved relatively downwardly along the mandrel which forces upper slips 28 outwardly and shears screws 36 to push upper slip wedge 32 downwardly against packer elements 40 and 42. Screws 50 are also sheared and lower slip wedge 46 is pushed downwardly toward lower slip support 58 to force lower slips 54 outwardly. Eventually, upper slips 28 and lower slips 54 are placed in gripping engagement with well bore 12 and packer elements 40 and 42 are in sealing engagement with the well bore. The action of upper slips 28 and 54 prevent packer 20 from being unset. As will be seen by those skilled in the art, pressure below packer 20 cannot force the packer out of well bore 12, but instead, causes it to be even more tightly engaged.

In prior art drillable packers and bridge plugs of this type, mandrel 22 is made of a medium hardness cast iron, and lock ring housing 24, upper slip wedge 32, lower slip wedge 46 and lower slip support 58 are made of soft cast iron for drillability. Most of the other components are made of aluminum, brass or rubber which, of course, are relatively easy to drill. Prior art upper and lower slips 28 and 54 are made of hard cast iron, but are grooved so that they will easily be broken up in small pieces when contacted by the drill bit during a drilling operation.

As previously described, the soft cast iron construction of lock ring housing 24, upper and lower slip wedges 32 and 46, and lower slip support 58 are adapted for relatively high pressure and temperature conditions, while a majority of well applications do not require a design for such conditions. Thus, the apparatus of the present invention, which is generally designed for pressures lower than 10,000 psi (68.9 MPa) and temperatures lower than 425°F (218°C), utilizes engineering frade plastics for at least some of the components. For example, one embodiment of the apparatus is designed for pressures up to about 5,000 psi (34.5 MPa) and temperatures up to about 250°F (121°C), although the invention is not intended to be limited to these particular conditions.

In a first preferred embodiment, at least some of the previously soft cast iron components of the slip means, such as the lock ring housing 24, upper and lower slip wedges 32 and 46 and lower slip support 58 are made of engineering grade plastics. In particular, upper and lower slip wedges 32 and 46 are subjected to substantially compressive loading. Since engineering grade plastics exhibit good strength in compression, they make excellent choices for use in components subjected to compressive loading. Lower slip support 58 is also subjected to substantially compressive loading and can be made of engineering grade plastic when packer 20 is subjected to relative low pressures and temperatures.

Lock ring housing 24 is mostly in compression, but does exhibit some tensile loading. However, in most situations, this tensile loading is minimal, and lock ring housing 24 may also be made of an engineering grade plastic of substantially the same

type as upper and lower slip wedges 32 and 46 and also lower slip housing 58.

Upper and lower slips 28 and 54 may also be of plastic in some applications. Hardened inserts for gripping well bore 12 when packer 20 is set may be required as part of the plastic slips.

Lock ring housing 24, upper slip wedge 32, lower slip wedge 46, and lower slip housing 58 comprise approximately 75% of the cast iron of the prior art squeeze packers. Thus, replacing these components with similar components made of engineering grade plastics will enhance the drillability of packer 20 and reduce the time and cost required therefor.

Mandrel 22 is subjected to tensile loading during setting and operation, and many plastics will not be acceptable materials therefor. However, some engineering plastics exhibit good tensile loading characteristics, so that construction of mandrel 22 from such plastics is possible. Reinforcements may be provided in the plastic resin as necessary.

Example

A packer 20 was constructed in which upper slip wedge 32 and lower slip wedge 46 were constructed by molding the parts to size from a phenolic resin plastic with glass reinforcement. The specific material used was Fiberite 4056J manufactured by Fiberite Corporation of Winona, Minnesota. This material is classified by the manufacturer as a two stage phenolic with glass reinforcement. It has a tensile strength of 18,000 psi (124 MPa) and a compressive strength of 40,000 psi (276 MPa).

The test packer 20 held to 8,500 psi (58.6 MPa) without failures to the wedges, more than sufficient for most well bore conditions.

Drilling Out The Packer Apparatus

Drilling out any packer apparatus 10, such as the illustrated packer 20, may be carried out by using a standard drill bit at the end of tubing string 16. Wire line drilling may also be used. With a standard "tri-cone" drill bit, the drilling operation is similar to that of the prior art except that variations in rotary speed and bit weight are not critical because the plastic materials are considerably softer than prior art cast iron, thus making packer 20 much easier to drill out. This greatly simplifies the drilling operation and reduces the cost and time thereof.

In addition to standard tri-cone drill bits, and particularly if packer 20 is constructed utilizing engineering grade plastics for mandrel 22 as well as for lock ring housing 24, upper slip wedge 32, lower slip wedge 46 and lower slip housing 58, alternate types of drill bits may be used which were impossible for packers constructed substantially of cast iron. For example, polycrystalline diamond compact (PDC) bits may be used. Drill bit 14 in FIG. 1 is illustrated as a PDC bit. Such drill bits have the advantage of having no moving parts which can jam up. Also, if the well bore itself was drilled with a PDC bit, it is not necessary to replace it with another or different type bit in order to drill out packer 20.

While a specific squeeze packer configuration of packing apparatus 10 has been described herein, it will be understood by those skilled in the art that other squeeze packers of this general configuration mentioned may also be constructed utilizing components selected of engineering grade plastics. Additionally, bridge plugs of this general configuration may also be manufactured with plastic components.

It will be seen, therefore, that the well bore packing packer apparatus and methods of drilling thereof of the present invention are well adapted to carry out the ends and advantages mentioned as well as those inherent therein. While a presently preferred embodiment of the apparatus and various drilling methods have been discussed for the purposes of this disclosure, numerous changes in the arrangement and construction of parts and the steps of the methods may be made by those skilled in the art.

Claims

1. A well bore process which comprises the steps of positioning a well packing device (10) into sealing engagement with the well bore (12); and subsequently drilling said device out of said well bore, characterised in that the device includes a component subject to substantially compressive loading which is made of a plastics material.

2. A process according to claim 1, wherein said device is a packer or a bridge plug.

3. A process according to claim 1 or 2, wherein said component in said device is a lock ring housing (24), slip (28,54), slip wedge (32,46) or slip support (24,58).

4. A process according to claim 1,2 or 3, wherein the device includes a component which is subject to at least some tensile loading and which is made of a plastics material.

5. A process according to claim 4, wherein said component subject to tensile loading is a centre mandrel (22) of said device.

6. A process according to any of claims 1 to 5, wherein said step of drilling is carried out with a polycrystalline diamond compact bit (14).

7. A well bore packing apparatus (10) which com-

prises a centre mandrel (22); slip means (28,32,46,54) disposed on said mandrel for grippingly engaging said well bore, said slip means comprising a slip wedge (32,46) made of a plastics material; and packing means (42) disposed on said mandrel for sealingly engaging said well bore when in a set position.

8. Apparatus according to claim 7, wherein said slip means comprises slips (28,54) also made of plastics material.

9. Apparatus according to claim 7 or 8, wherein said mandrel is also made of a plastics material.

10. Apparatus according to claim 7,8 or 9, wherein said plastics material is a glass reinforced phenolic resin.

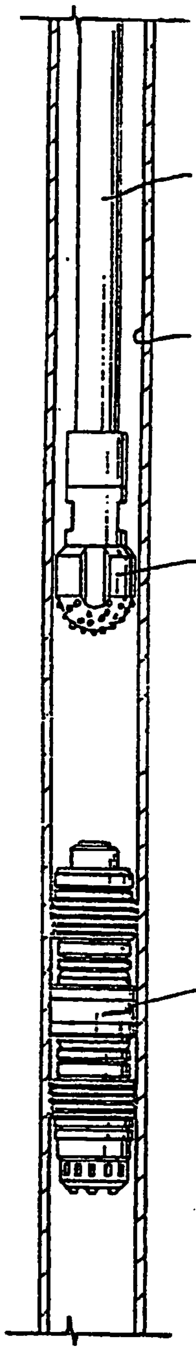
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FIG. 1

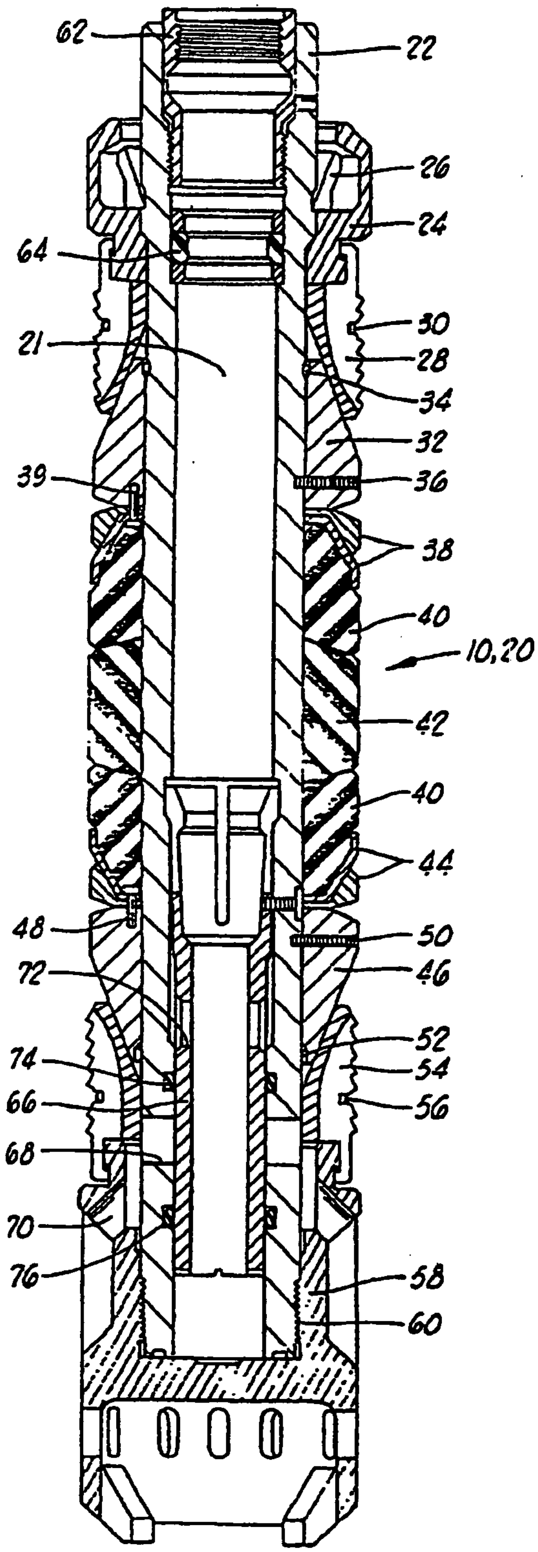
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FIG. 2

Borehole Plug

The present invention is a plug which is devised for use in stopping up boreholes.

When a borehole is being drilled, for example in investigating the make-up of successive layers of rock or other materials, it is frequently desired to seal the borehole completely at some point in its depth. Typically it is desired to form a cement seal to close off the borehole at that point. For this purpose, it has been proposed to locate a metal plug just above that depth and then to inject a suitable grout through the plug, which grout then sets to form the desired seal.

One available form of plug comprises two axially aligned, cylindrical steel members which can be screwed closer together *in situ* to expand a rubber sleeve located between them, to cause the rubber sleeve to seal against the wall of the borehole and thereby hold the plug in place during subsequent injection of grout. In order to lock one of the steel members against rotation while the other member is screwed on to it, that first member is provided with a pair of resilient steel fingers, which

extend forwardly with respect to the plug (that is, further into the borehole) and are urged radially outwardly by their resilience into contact with the wall of the borehole.

This prior available plug suffers from at least two important disadvantages in use. Firstly, when drilling in mineral-bearing formations such as coal, it is not unusual to encounter flammable and/or explosive gases and it is therefore important to avoid using materials, such as steel, which can give rise to sparks. Secondly, the plug offers only a limited resistance to axial movement in a rearward direction and may therefore become displaced under pressure from the grout or other material in the borehole.

It is an object of the present invention to provide an improved form of borehole plug, in which the foregoing disadvantages of the existing plug are reduced or eliminated.

The borehole plug according to the present invention comprises two axially aligned, generally cylindrical members having aligned axial bores therein, a generally cylindrical hollow sleeve of a resilient material disposed between those members and in mutual axial alignment with them, the generally cylindrical members being formed of a synthetic polymeric material and being in threaded mutual engagement to permit their relative axial movement, whereby

to apply an axially compressive force to the hollow sleeve, one or more brass dogs, pivoted within the region of a first end (the "forward" end) of the plug and urged in a generally radially outward and rearwardly-facing direction by spring means, rotational drive means adapted to engage the second end (the "rearward" end) of the plug, and a shear pin, located to provide a rigid connection between the drive means and the plug and adapted to break when the rotational force upon the plug exceeds a predetermined value.

In the following description, the words "forward" and "rearward" refer to the positions and movement of the plug relative to the borehole, in that the forward end of the plug is disposed further into the borehole than the rearward end.

The aligned generally cylindrical members are made of a synthetic polymeric material and therefore are not prone to generating sparks like the steel hitherto used for existing such plugs. The particular material used is selected according to the desired properties but in general is preferably a hard and rigid material. Various nylons are suitable for this purpose, among which may specifically be mentioned nylon 66 and also the material sold by the firm Polypenco Limited under the trade name Nylatron GSM. The latter is a partially cross-linked nylon 6 material modified by

the addition of molybdenum sulphide. The preferred materials are laminated phenolic resins, of which the most preferred is the fabric-laminated phenolic resin sold by Tufnol Ltd. as their "Whale" brand, modified by coating with graphite particles to enhance its antistatic properties.

The generally cylindrical hollow sleeve is located between the two generally cylindrical members such that these members may move relative to each other to squeeze the sleeve between them and thereby expand it in a radially outward direction. To this end, the members are threaded together so that when they are rotated relative to each other they move together in an axial direction to apply compression to the ends of the sleeve. The sleeve is formed of a resilient material such as a natural or synthetic rubber.

Adjacent to the forward end of the plug, upon the adjacent generally cylindrical member, one or more brass dogs are pivoted. Preferably at least two brass dogs are provided, preferably symmetrically disposed around the circumference of the member. In a particularly preferred form of the invention there are four such brass dogs. By virtue of their pivoting, and under pressure from associated spring means, the dogs are urged generally radially outwardly relative to the plug such that their outer ends are directed towards the rearward end of the plug. In this position they perform two functions. Firstly, by engaging the wall of the borehole, they hold the forward member against rotation and thereby allow relative rotation of the two members. Secondly, the fact that they are rearwardly directed means that they assist the sleeve, once expanded, in

resisting pressures within the borehole tending to eject the plug from the borehole.

The spring means provided to urge the brass dogs outwardly may conveniently be rubber springs located, for example in sockets, between the dogs and the adjacent generally cylindrical member.

Rotation of the rearward member is effected by a rotational drive means which engages the rearward end of the plug and is connected to the plug by a shear pin. The drive means conveniently takes the form of an adaptor, driven in turn by the drilling line. The adaptor may, for example, include a short cylindrical section which enters the bore in the rearward member and is held there by a radially-directed shear pin.

The shear pin transmits the drive to the rearward member of the plug and is designed to break when the sleeve has been expanded to such an extent that further relative rotation of the two members would, without the shear pin, damage the members, for example by breaking the threads thereon. The shear pin may be of brass.

The plug may be used in order to enable a cement seal to be formed in the borehole or may, in appropriate circumstances, itself form the seal. For the first purpose, it is necessary to inject a suitable grout via the axial bore extending through the plug and a non-return valve is then provided at the forward end

of the plug. In a preferred form, the valve is a simple flap, for example of brass, pivoted so as to close the forward end of the axial bore. Preferably, the pivoting of the flap is limited to ensure that it will always return under rearward pressure from the grout. For example, it may be restricted to a maximum angular movement of the order of 30 degrees between its closed and its fully open positions.

Alternatively, the plug may be formed closed at its forward end, in which case it may be used for itself sealing off a borehole without the use of cement.

As underground conditions change or the requirements of a borehole are modified, it may be desired to reopen a sealed borehole. For this purpose, the flap or closed end of the plug may readily be drilled through or the whole plug may be drilled out and these operations are rendered much easier by virtue of the specified materials of construction of the plug.

The invention will now be further described with reference to the accompanying drawing which illustrates, by way of example only, one preferred embodiment of the borehole plug according to the present invention, shown in axial cross-section.

The illustrated plug comprises a forward member 10 formed, for example, of graphite-coated Tufnol "Whale" brand fabric-laminated phenolic resin and in threaded engagement with a rearward member 11 of the same material. Aligned

with these two members and surrounding the threaded sections of the members is a neoprene rubber sleeve 12. The sleeve 12 is graded with harder rubber in its end sections and a softer rubber in its central section. An axial bore 13, which extends through the two aligned members 10 and 11, is closed off at the forward end of the plug (at the left of the plug as illustrated) by a brass flap 14, pivoted to the member 10 upon a brass pivot 15. A stop 16 limits the opening movement of the flap 14 to a maximum angle of 30 degrees.

At the forward end of the member 10, four brass dogs 17 are pivoted upon/brass pivots 18, which are symmetrically located around that end. Rubber springs 19, housed in sockets 20 in the member 10, urge the dogs 17 radially outwardly so that, when they are free to do so, they point in the direction of the rear of the plug.

An adaptor 21, shown in broken lines in the drawing, has a short cylindrical extension 22 which is introduced into the member 11 and retained there by a brass shear pin 23. The adaptor 21 and shear pin 23 allow a rotary drive to be imparted to the member 11.

When the illustrated plug is to be used to allow a concrete seal to be formed in a borehole, the plug is fitted to the adaptor 21 as illustrated and introduced by the drill string to a position in the borehole just short of the desired position of the seal. The dogs 18

readily retract to allow movement of the plug into the borehole but, under pressure from the rubber springs 19, they are able to engage the wall of the borehole and thereby prevent rotation of the member 10. Thus, when the member 11 is now rotated via the adaptor 21, this member advances along the threads of the member 10 and squeezes the rubber sleeve 12, thus causing the sleeve to expand outwardly into engagement with the wall of the borehole. When the resistance to further rotation of the member 11 reaches a predetermined value, selected to prevent damage to the threads on the two members, the shear pin 23 breaks, thereby disconnecting the adaptor 21 from the member 11.

A suitable grout is now introduced, via the drill string and the adaptor 21, into and through the plug and beyond the flap 14 into the borehole. The flap 14 prevents backflow of the grout from the hole. When a desired pressure has been established in the grout in the borehole, the drill string and adaptor 21 are withdrawn for cleaning and re-use.

CLAIMS

1. A plug for a borehole, which plug comprises two axially aligned, generally cylindrical members having aligned axial bores therein, a generally cylindrical hollow sleeve of a resilient material disposed between those members and in mutual axial alignment with them, the generally cylindrical members being formed of a synthetic polymeric material and being in threaded mutual engagement to permit their relative axial movement, whereby to apply an axially compressive force to the hollow sleeve, one or more brass dogs, pivoted within the region of a first end (the "forward" end) of the plug and urged in a generally radially outward and rearwardly-facing direction by spring means, rotational drive means adapted to engage the second end (the "rearward" end) of the plug, and a shear pin, located to provide a rigid connection between the drive means and the plug and adapted to break when the rotational force upon the plug exceeds a predetermined value.

2. A borehole plug as claimed in claim 1, wherein the synthetic polymeric material is a nylon.

3. A borehole plug as claimed in claim 1, wherein the synthetic polymeric material is a laminated phenolic resin.

4. A borehole plug as claimed in any of the preceding claims, wherein the resilient material is a natural or synthetic rubber.

5. A borehole plug as claimed in any of the preceding claims, comprising at least two said brass dogs.

6. A borehole plug as claimed in any of the preceding claims, wherein the spring means comprises one or more rubber springs located between the brass dog(s) and the adjacent generally cylindrical member.

7. A borehole plug as claimed in any of the preceding claims, wherein the rotational drive means comprises an adaptor, driven in turn by the drilling line.

8. A borehole plug as claimed in claim 7, wherein the adaptor includes a short cylindrical section which is adapted to enter the bore in the rearward generally cylindrical member and to be held there by a radially-directed shear pin.

9. A borehole plug as claimed in any of the preceding claims, wherein the shear pin is of brass.

10. A borehole plug as claimed in any of the preceding claims, having a non-return valve at its forward end.

11. A borehole plug as claimed in claim 10, wherein the non-return valve is a pivoted flap.

12. A plug for a borehole, substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

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